

## CONNECTED VEHICLE REFERENCE IMPLEMENTATION ARCHITECTURE

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The Connected Vehicle Reference Implementation Architecture (CVRIA) project is focused on developing a connected vehicle reference implementation architecture for applications and systems, as well as develop an integrated standards strategy and action plan.<sup>54</sup> The project is systematically documenting and prioritizing interfaces, standards, and gaps. As part of this process, CVRIA is engaging key stakeholders for input and communication through opportunities such as workshops, websites, and review of documents. The project will also identify relevant policy issues and consider opportunities for harmonization.

## UNITED STATES DEPARTMENT OF TRANSPORTATION

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United States federal agencies are not explicit SDOs. However, these agencies (e.g., NHTSA, FTA, FHWA) have regulatory authority that includes the ability to mandate certain standards be implemented into vehicle and infrastructure technology. Because of this inherent interest in the standards development process, USDOT has been an active participant in standardization and harmonization activities.

### 3.3 DIFFERENCES BETWEEN THE UNITED STATES AND EUROPEAN UNION STANDARDS

Different types of standards that are of prime importance include standards associated with the applications (i.e. application layer), 5.9 GHz spectrum allocation (i.e. access layer) and security (i.e. security layer). This is because some standards will be dependent on the applications and functionality that need to be deployed. It is considered that a minimum set of standards is required in order to deploy the core functions of C-ITS and to deliver the applications which local stakeholders wish to deploy early.

As discussed in previous chapter, the United States is currently developing a WAVE Protocol architecture (IEEE 1609.0) that is focused on a 5.9 GHz radio interface as opposed to supporting multiple network stacks proposed by the European Union (e.g., ETSI set of standards which focus on 5.9 GHz

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<sup>54</sup> CVRIA (2015). Connected Vehicle Reference Implementation Architecture. Website. Accessed February 25, 2015. <<http://www.iteris.com/cvria/>>.

DSRC and the CEN/ISO which focuses on the concept of a platform using multiple communications). The WAVE protocol architecture is separate from the U.S. Connected Vehicle Reference Implementation Architecture (CVRIA) project.

The United States has set aside a 70 MHz spectrum within the 5.9 GHz band (5.855-5.925 GHz) and Europe has set aside a 50 MHz spectrum (5.855-5.905 GHz). While the spectrum set-asides are not in exact alignment, DSRC hardware will likely be able to comply with both the U.S. and European standards, though there will be some necessary software differences. It is understood the U.S. scenario aims to standardize the interfaces while the EU scenario is creating an ITS station which would manage all communications within the one platform. For example, the EU scenario will facilitate a hazard warning application being delivered via a hazard-warning message from another vehicle via V2V 5.9 GHz DSRC, from roadside infrastructure via infrastructure-to-vehicle (I2V) 5.9 GHz DSRC or from a central office via cellular communications. At this stage, it is unclear how the United States will manage C-ITS applications that could be delivered via multiple communications as its focus is on delivering critical safety (low latency) via 5.9 GHz DSRC.

Having two platforms (e.g. 5.9 GHz DSRC and cellular based) may be an issue for applications that may be delivered via either platform (e.g. hazard warning application which could obtain a hazard warning message from another vehicle via V2V 5.9 GHz DSRC, from roadside infrastructure via I2V 5.9 GHz DSRC or from a central office via cellular communications). In this case, the application may need to identify the communication platform (or technology) it will transmit a message. U.S. standards use the basic safety message (BSM), while European standards use a cooperative awareness message (CAM) and a decentralized environmental notification message (DENM).

Both the U.S. and EU scenarios concentrate on 5.9 GHz communications, however, the EU scenario has a clearer path towards the use of hybrid communications (through the proposed CALM approach) than does the U.S. scenario. As such, the EU scenario is considered more integrated and scalable.

### 3.4 INTERNATIONAL HARMONIZATION EFFORTS

Though some of the key stakeholders and regions have signed memorandums of cooperation (MOCs) to work together and harmonize connected vehicle

standards where possible, different platforms are emerging in different countries. The United States and Europe signed a joint declaration in 2009 pledging to use global standards when possible.<sup>55</sup> The U.S. signed similar agreements with Canada and Japan in 2010 and one with South Korea in 2012.<sup>56</sup> There is also active cooperation between the IEEE, SAE, and ISO groups to harmonize and work towards developing a single harmonized set of standards, with possible regional options where needed.<sup>57</sup>

The adoption of multiple standards within a given area of interest should be limited to those cases where there are demonstrated technical needs, such as differing frequency spectrum allocations, and legal requirements, such as privacy protection laws. The parties welcome participation of other countries and regions, particularly those of the Asia Pacific region, in the development of global open, harmonized standards for C-ITS.

From the perspective of all three sets of standards and the standardization of C-ITS, standards are considered to be either:

- Not yet available (i.e. gaps): These will be completed as part of the finalization of the release 1 set of standards and as part of additional standards releases as C-ITS evolves (discussed further in Section 2.9). Further, while there may be regional differences in C-ITS hardware, it should function irrespective of the region in which it is deployed. The main gaps will be software.
- Competing but compatible with one another: Standards within opposing sets that deal with the same element of C-ITS but in a harmonized and compatible manner.
- Competing and non-compatible with one another: Standards within opposing sets that deal with the same/similar element of C-ITS but in a non-compatible manner.
- Complementary to one another: Standards that should be complementary to one another.

USDOT coordinates, collaborates, and generally exchanges information with transportation agencies from around the world. USDOT has also entered into

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<sup>55</sup> RITA 2009.

<sup>56</sup> RITA 2010.

<sup>57</sup> Evensen and Schmitting 2014.

formal cooperative agreements to coordinate ITS research and development efforts.<sup>58</sup>

#### EU-U.S. JOINT DECLARATION OF INTENT ON RESEARCH COOPERATION IN COOPERATIVE SYSTEMS

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Transportation agencies representing both the European Union and United States released a Joint Declaration of Intent on Research Cooperation in Cooperative Systems in 2009.<sup>59</sup> As outlined by Evensen (2013) harmonization is happening rapidly. As part of the EU-U.S. activities, the task group is considering work that will outline gaps and areas of overlap with respect to standards harmonization.

One essential component of this agreement was a passage directed at independent standards organizations encouraging global harmonization of standards. The related passage is outlined in Cadzow et al. (2012) as follows:

Globally harmonized standards are essential to support and accelerate the deployment and adoption of Cooperative Systems. The parties strongly support development of global open standards which ensure interoperability through appropriate actions including, but not limited to, coordinating the activities of standardization organizations. In particular, the parties intend to preclude the development and adoption of redundant standards.<sup>60</sup>

Further, the European Union and United States have agreed to cooperate in ITS research in order to achieve interoperability on a national/regional level with a focus on creating a global market for ITS products and services with minimal trade barriers.<sup>61</sup> The key goals of the EU-US harmonization activities are:

- a globally harmonized message containing all radio frequency parameters subject to regulation
- a globally harmonized message containing all security, privacy, and authenticity-related parameters
- a globally harmonized protocol for the exchange of such information between ITS stations and the appropriate regulatory authorities.

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<sup>58</sup> [http://www.its.dot.gov/connected\\_vehicle/international\\_research.htm](http://www.its.dot.gov/connected_vehicle/international_research.htm)

<sup>59</sup> [http://its-standards.info/eu\\_us\\_joint\\_decl\\_on\\_coop\\_systems.pdf](http://its-standards.info/eu_us_joint_decl_on_coop_systems.pdf), accessed April 2015.

<sup>60</sup> Cadzow et al. 2012.

<sup>61</sup> Cadzow et al. 2012.

To move forward with harmonization, the EU and U.S. ITS Standards Program has facilitated activities launching harmonization efforts, established relevant relationships with appropriate U.S. and international entities, and reached out to new entities. At the technical level, established six Harmonization Task Groups (HTGs) to jointly execute activities:

- HTG #1: Service and security management to support joint applications.
- HTG #2: Harmonization of the core safety message set.
- HTG #3: Joint protocols for safety and sustainability services.
- HTG #4/5: Harmonization of broader message sets and data dictionaries, including interface standards supporting applications for signalized intersections.
- HTG #6: Harmonization of relevant aspects of security policies

HTG #1, #2, and #3 completed work during 2013.<sup>62</sup>

#### U.S.-JAPAN TECHNICAL COOPERATION AND INFORMATION EXCHANGE

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USDOT has a long history of research exchange and collaboration with Japan's Ministry of Land, Infrastructure, Transport, and Tourism (MLIT). In 2010, USDOT and MLIT signed a Memorandum of Cooperation regarding ITS.<sup>63</sup> The four high-priority areas of collaboration are:<sup>64</sup>

- Probe Data
- Evaluation Tools and Methods
- International Standards Harmonization
- Automation in Road Transport (trilateral with the European Union).

#### U.S.-SOUTH KOREA COLLABORATIVE AGREEMENT

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In 2012, USDOT signed an Implementing Arrangement with the Korean Ministry of Land, Transport, and Maritime Affairs (MLTM) to collaborate on ITS research.<sup>65</sup> Initial collaboration regards information sharing and lessons learned from pilot deployments.<sup>66</sup>

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<sup>62</sup> [http://www.its.dot.gov/connected\\_vehicle/connected\\_vehicle\\_standards\\_progress.htm](http://www.its.dot.gov/connected_vehicle/connected_vehicle_standards_progress.htm)

<sup>63</sup> Cronin 2012.

<sup>64</sup> USDOT. Web Site. Connected Vehicle Technology/International Research.

<sup>65</sup> Cronin 2012.

<sup>66</sup> Leonard 2014.

### CANADA-U.S. REGULATORY COOPERATIVE COUNCIL

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Transport Canada (TC) and USDOT established a mechanism for coordinating updates to their national ITS architectures to ensure that technology deployments in both countries adhere to the same manufacturing and operating standards, thereby reducing development and implementation costs. Ongoing alignment work on ITS is supported by two Memoranda of Cooperation signed in 2010. TC and the FHWA jointly developed an implementation plan for the installation of Border Wait Time measurement systems at priority international border crossings and completed pilot projects at two bridge crossings in the Buffalo/Niagara Falls area, which will facilitate additional deployments on the Canada-U.S. border. TC and USDOT worked with the American Association of State Highway and Transportation Officials (AASHTO) on the field infrastructure footprint analysis project which will help ensure coordinated deployment of connected vehicles technology with state departments of transportation (DOTs). V2V communication technology for light-duty vehicles could become a potential area of Regulatory Cooperative Council (RCC) focus moving forward.<sup>67</sup>

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<sup>67</sup> U.S.-Canada Regulatory Cooperation Council. *Joint Forward Plan*. August 2014.

## 4 CONNECTED VEHICLE STANDARDS HARMONIZATION SURVEY

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The Connected Vehicle Standards Harmonization Survey was sent to targeted individuals known for their expertise in connected vehicles and familiarity with standards harmonization. The survey used a combination of Likert scale, multiple choice, and open-ended responses to determine the status and implications of connected vehicle standards harmonization. The survey was completed by nineteen individuals, ten of whom gave permission to be identified in this report. A list of these individuals and their affiliation is provided in Appendix B. This section provides a summary of responses to each question.

### 4.1 IMPORTANCE OF HARMONIZATION

Question 1: “How important is it to develop internationally harmonized connected vehicle standards?”

This question asked respondents to rate the importance of developing internationally harmonized connected vehicle standards on a 1-7 Likert scale, with one meaning “not important,” and seven meaning “very important.” Thirteen of the nineteen respondents chose a six or seven—implying that respondents generally believe international harmonization to be a very important activity (Figure 6). One respondent described international harmonization as “not important.”

### 4.2 CURRENT STATE OF HARMONIZATION

Question 2: “How would you describe the state of connected vehicle interoperability and standards harmonization between vehicle markets (e.g., European Union, Japan, China, etc.)?”

This question asked respondents to rate the state of harmonization on a 1-7 Likert scale, with one meaning “no harmonization,” and seven meaning “ideal harmonization.” Most respondents chose a neutral value, indicating “some harmonization” (Figure 7).

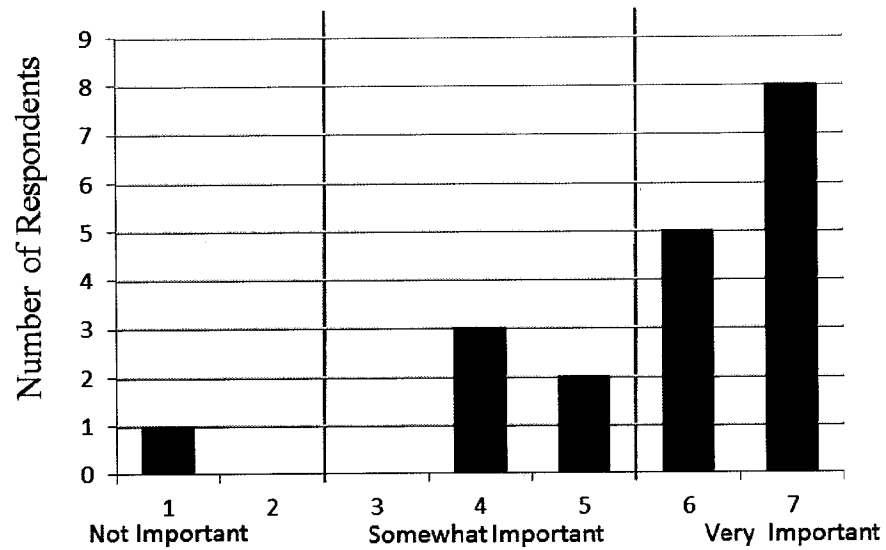


FIGURE 6: SURVEY RESULTS: IMPORTANCE OF INTERNATIONAL HARMONIZATION OF CONNECTED VEHICLE STANDARDS

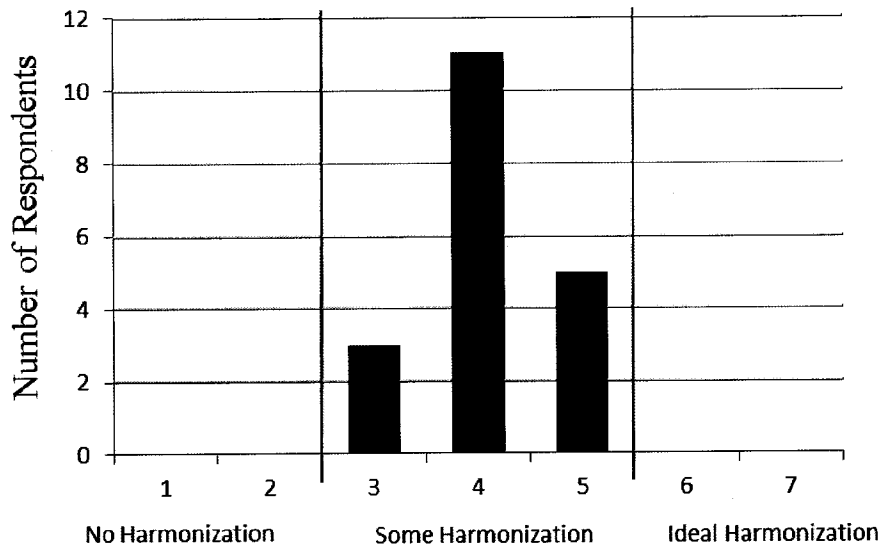


FIGURE 7: SURVEY RESULTS: STATE OF CONNECTED VEHICLE STANDARDS HARMONIZATION

### 4.3 BEST APPROACH

Question 3: “Do you perceive any specific set of connected vehicle/C-ITS standards as preferable for successful V2X/C-ITS?”

This question asked respondents to determine which approach to connected vehicle standards is preferable between U.S., EU, and Japanese approaches. Ten of the nineteen respondents chose the U.S. approach as preferable. Four chose the EU approach as preferable. No respondents indicated the Japanese approach is preferable. The remaining five reported that none of the approaches was clearly better. It is important to note that U.S. interests were far more represented in this survey than EU, and none of the respondents are known to be based in Japan.

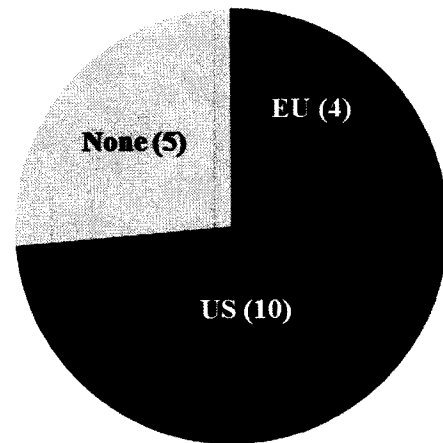


FIGURE 8: SURVEY RESULTS: PREFERRED SET OF CONNECTED VEHICLE STANDARDS

### 4.4 EFFECT ON CONNECTED VEHICLE APPLICATIONS

Question 4: “How might international harmonization (or lack thereof) affect development of connected vehicle applications?”

Respondents generally indicate that the primary benefit of harmonization is to develop a global marketplace for connected vehicle technologies and applications, allowing the connected vehicle industry to take advantage of economies of scale. If automakers and technology developers can target a broad global market, there will be reduced production costs and thus accelerated deployment and adoption of connected vehicle technologies. While most respondents indicate that this is primarily an issue for the private sector, one respondent pointed out that non-harmonization also increases the amount of public funds necessary to develop, test, and deploy connected vehicle systems because “different message sets and interfaces will impede the ability to transfer applications and lessons learned between different regions.”

One respondent (representing a Tier 1 supplier) offered a different perspective: “I do not see [lack of harmonization] as a big concern, as many

factors can work against effective harmonization, such as road conditions, bldg., infrastructure, etc.”

Two respondents did not provide a response to this question.

## 4.5 SPECIFIC CONFLICTS

Question 5: “Please list any specifically conflicting standards that are complicating connected vehicle application development and/or deployment.”

Nine of the nineteen respondents provided a response to question five, which requested specific conflicting standards complicating connected vehicle technology development. Three respondents referenced general mismatch of spectrum and channel allocation. One respondent indicated that there should be more work determining how cellular networks will be integrated. Specific answers include the following:

- “IEEE 1609.2 conflicts with ETSI TS 103 097”
- “IEEE 1609.3 conflicts with the ETSI geonetworking standards”
- “SAE J2735 and IEEE 1609 vs. ETSI”
- “SAE J2735 vs. ETSI TS 102 637-2”

Additionally, one respondent mentioned that the Japanese approach uses an entirely different set of standards from either the EU or U.S. approaches.

## 4.6 FEDERAL GOVERNMENT INVOLVEMENT

Question 6: “Please note the extent to which you agree or disagree with the following statement: Involvement of central governments will be essential to achieving desirable levels of connected vehicle standards harmonization.”

Respondents generally indicated a belief that government involvement will be advantageous, if not essential to developing connected vehicle standard harmonization. Though two respondents disagreed, most were on the neutral to agreeable end of the Likert scale (Figure 9).

## 4.7 STATE/LOCAL GOVERNMENT INVOLVEMENT

Question 7: “Please note the extent to which you agree or disagree with the following statement: Involvement of regional governments (e.g., U.S. states) will be essential to achieving desirable levels of connected vehicle standards harmonization.”

Respondents generally disagreed, or were neutral, towards the idea that regional governments like state government involvement would be necessary to develop connected vehicle standards harmonization (Figure 10).

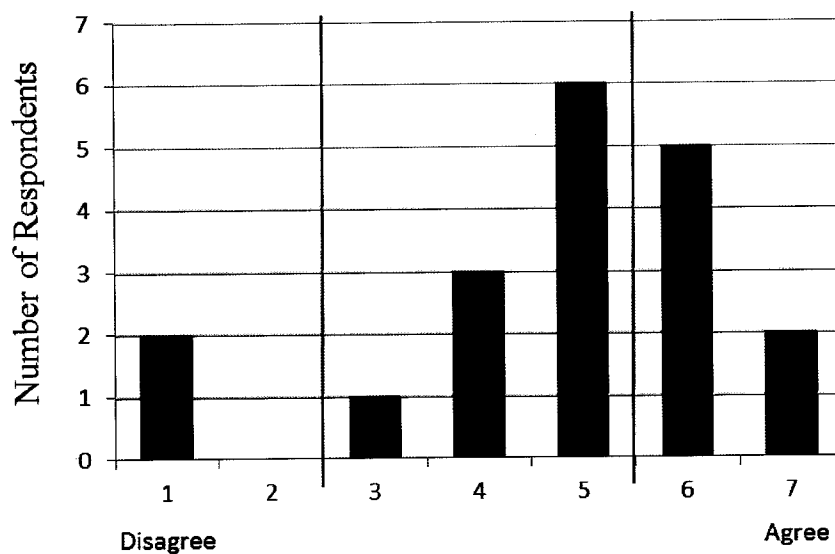


FIGURE 9: SURVEY RESULTS: RESPONDENT AGREEMENT THAT *CENTRAL* GOVERNMENT INVOLVEMENT WILL BE ESSENTIAL TO CONNECTED VEHICLE HARMONIZATION.

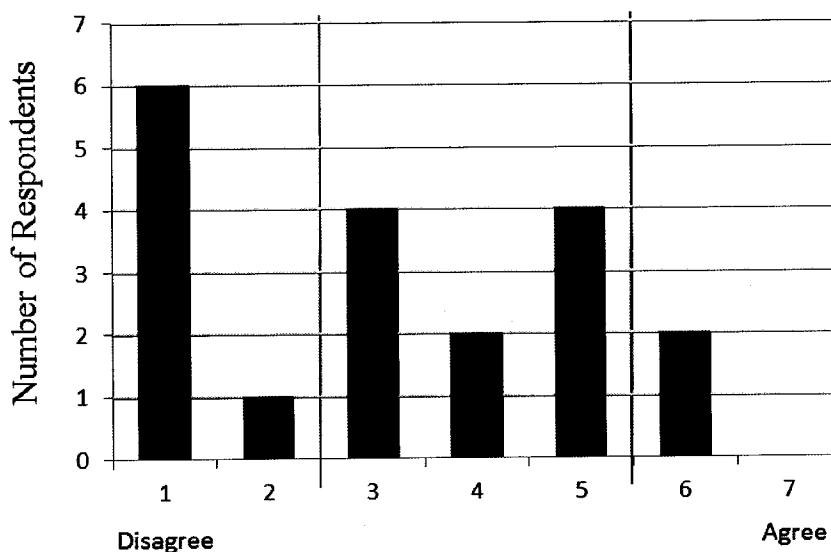


FIGURE 10: SURVEY RESULTS: RESPONDENT AGREEMENT THAT *REGIONAL* (I.E., STATE) GOVERNMENT INVOLVEMENT WILL BE ESSENTIAL TO HARMONIZATION.

## 4.8 IMPORTANCE OF PUBLIC-PRIVATE PARTNERSHIPS

Question 8: “How important are public-private partnerships to the deployment of connected vehicle technology?”

Respondents rated public-private partnerships as relatively important to deployment of connected vehicles (Figure 11).

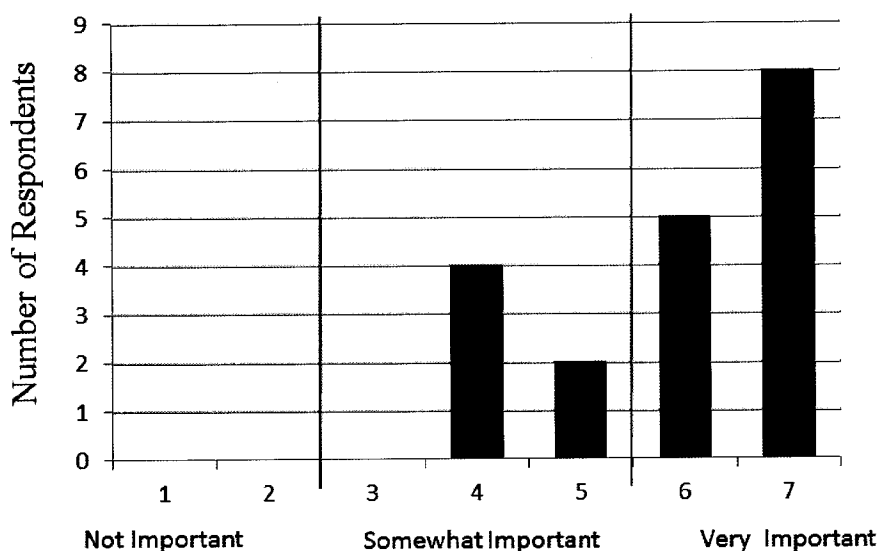


FIGURE 11: SURVEY RESULTS: IMPORTANCE OF PUBLIC-PRIVATE PARTNERSHIPS

## 4.9 OPEN COMMENTS

Question 9: “In the space below, please provide any additional comments you have regarding connected vehicle standards harmonization.”

Respondents were allowed to provide any additional information they considered important regarding standards harmonization. Nine respondents took advantage of this opportunity. Most respondents indicated that standards harmonization is important for connected vehicle deployment and is beneficial to many parties (consumers, producers, regulators). The role of the government in developing these standards is debated (funding and outreach vs. development). A minority expresses concern over harmonization as being harmful to other standards and to the deployment of connected vehicles. All responses are provided below in no particular order.<sup>68</sup>

<sup>68</sup> Some comments were lightly edited for punctuation and grammar only.

“Harmonization of certification testing standards and processes is essential to the ability to bring a device from one region to another and have it stay trusted.”

“The standards should be forward-looking and allow for easy migration from current standards to future ones.”

“The opportunity for private enterprises, consumers, and governments is almost unimaginable. Harmonizing these efforts will lead to tremendous value for consumers and immense revenue opportunities for all constituents.”

“Aside from spectrum, government should not be significantly involved in standards (aside from pushing/funding them). This is an industry issue. The state and local governments should not be involved in standards development; they should be involved in standards *implementation* for V2I.”

“For harmonization of standards the governments have a role but not necessarily the central role. On the other hand, governments do need to discuss and harmonize *policies* that will, in turn, affect connected vehicle deployment and standards harmonization.”

“International standards harmonization activities should not be allowed to slow the deployment of connected vehicles, and should also not subsequently strand an installed base of connected vehicles.”

“The broadcast-enabled TPEG Standards ([www.tisa.org](http://www.tisa.org)) need to be considered as one important part—even in pure connected scenarios.

“Attempts to “harmonize” IEEE and ISO ITS standards are slowing, complicating, and compromising the development of quality IEEE standards.”

“Significant work is already being undertaken by USDOT and automobile OEMs. Difficulty is in the breadth of required work and resource availability.”

## 5 CONCLUSIONS AND RECOMMENDATIONS

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Connected-ITS applications combine traditional aspects of connected vehicle systems and ITS infrastructure. For C-ITS to function most effectively, there must be interoperability between the ITS infrastructure and vehicle equipment across the fleet. All automakers and infrastructure operators must deploy equipment conforming to a harmonized set of standards. Such cross-organizational standards are usually developed through independent SDOs in coordination with effected government and private interests.

The USDOT Connected Vehicle Program is working towards deployment of a single nationwide connected vehicle network for ITS applications. USDOT does not directly set standards, but can adopt (and influence) standards developed by independent SDOs. The USDOT Connected Vehicle Program utilizes standards from SDOs such as SAE International and IEEE.

Only vehicles with connectivity equipment and software conforming to network standards would be able to operate within a specific C-ITS environment. The connected vehicle network must include security provisions to ensure that each device is valid and not malfunctioning. This implies that in addition to standardized vehicle and infrastructure equipment, the back-office network administration and security process must be standardized and integrated.

At this time, there is no movement towards establishing a truly harmonized set of standards that would allow a single connected vehicle to operate within any C-ITS network across the globe. Thus, for example, it is not likely that a connected vehicle conforming to European standards could connect to C-ITS infrastructure in the US. However, there are significant efforts towards developing connected vehicle standards that are close enough that automakers, governments, and C-ITS technology developers could adopt analogous conceptual and technological frameworks across markets.

C-ITS stakeholders widely believe that such international harmonization of ITS standards will accelerate the deployment of C-ITS systems across the globe by leveraging economies of scale to research, development, and manufacturing activities. The accelerated deployment of C-ITS applications could have broad public benefit, as such technologies are being developed with the intent of improving safety, mobility, and efficiency of the transportation system. This potentially broad social benefit has encouraged

USDOT to coordinate with international agencies in pushing for the greatest possible harmonization of C-ITS standards.

While public transportation agencies have an interest in encouraging internationally harmonized C-ITS, standards-development is primarily a private-sector activity. National governments have some direct authority over certain aspects of C-ITS, such as spectrum allocation. However, governments usually do not have the expertise or authority to directly influence industry standards. Even federal agencies, such as USDOT, must typically wait for appropriate standards to be developed by independent SDOs; only when standards are adopted by SDOs can they be effectively integrated into policy.

Regional governments such as MDOT may have eventual authority over C-ITS infrastructure, and thus have some interest in the standards integrated into C-ITS systems. However, it is difficult to envision how regional governments could have much direct influence over standards development or harmonization processes at this time. If regional governments have well-defined and specific insight to contribute to ongoing standards developments and harmonization activities, they may consider assigning knowledgeable representatives to participate in such activities. Otherwise, regional governments are generally involved in *implementation* of standards. Until USDOT successfully adopts a nationwide C-ITS policy including specific standards, state transportation agencies are generally relegated to observer status while SDOs, industry groups, and national governments work towards standards harmonization and adoption.

The Michigan Department of Transportation is positioned to be a leading adopter of connected vehicle technology if/when USDOT adopts and implements a standardized connected vehicle platform. MDOT has participated in several connected vehicle research and test-bed projects, including the installation of roadside infrastructure conforming to the latest available standards. While MDOT is not in a position to directly influence the development or harmonization of connected vehicle standards, MDOT will sustain a leadership position by actively following standards development and harmonization processes, as well as maintaining in-house expertise on the latest advancements in standards development.

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- Vehicular Networking: Automotive Applications and Beyond*. Ed. Marc Emmelman, Bernd Bochow, and C. Christopher Kellum. John Wiley and Sons, Ltd. ISBN: 978-0-47074151-2. 2010
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## APPENDIX A: LIST OF ABBREVIATIONS

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2/3/4G	Second/Third/Fourth Generation (cellular technology)
AASHTO	American Association of State Highway and Transportation Officials
ACI	Adjacent Channel Interference
AEC	Automotive Electronics Council
ANSI	American National Standards Institute
ARIB	Association of Radio Industries and Businesses [Japan]
ASTM	[Formerly] American Society for Testing and Materials
BSM	Basic Safety Message
C2C-CC	Car-to-Car Communications Consortium
CALM	Communications Access for Land Mobiles
CAM	Cooperative Awareness Message
CAMP	Crash Avoidance Metric Partnership
CAN	Controller Area Network
CATARC	China Automotive Technology and Research Center
CCH	Control Channel
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardizations
C-ITS	Cooperative Intelligent Transportation System
CV	Connected Vehicle
CVRIA	Connected Vehicle Reference Implementation Architecture
DENM	Decentralized Environmental Notification Message
DSRC	Dedicated Short-range Communications
EAN	Extended Area Network
EFTA	European Free Trade Agreement
ERTICO	ITS Europe
ETC	Electronic Toll Collection
ETSI	European Telecommunications Institute
EU	European Union

FCC	Federal Communications Commission
FDD-LTE	Frequency Division Duplex LTE
FHWA	Federal Highway Administration
FTA	Federal Transit Authority
HAP	Harmonization Action Plan
HD	High Definition
I2V	Infrastructure-to-Vehicle
IAN	Incident Area Network
ICT	Information and Communications Technology
IDA	Infocomm Development Authority (Singapore)
IEC	International Electro-technical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEEE-SA	IEEE Standards Association
IETF	Internet Engineering Task Force
IP	Internet Protocol
ISO	International Organization for Standardization
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITS JPO	ITS Joint Program Office
ITSC	Information Technology Standards Committee (Singapore)
ITSTC	Intelligent Transport Systems Technical Committee (Singapore)
JAN	Jurisdictional Area Network
JARI	Japan Automobile Research Institute
JSAE	Society of Automotive Engineers of Japan
KATS	Korean Agency for Technology and Standards
LLC	Logical Link Control [layer]
LTE	Long-term Evolution [cellular technology]
MAC	Medium Access Control
MDOT	Michigan Department of Transportation

MIIT	Ministry of Industry and Information Technology
MLIT	Ministry of Land Infrastructure Transport, and Tourism (Japan)
MLTM	Ministry of Land, Transport, and Maritime Affairs (South Korea)
MOC	Memorandum of Cooperation
NEMA	National Electrical Manufacturers Association
NHTSA	National Highway Traffic Safety Authority
NTCIP	National Transportation Communications for Intelligent Transportation Systems Protocol
OBD	On-board Diagnosis
OBU	On-board Unit
OEM	Original Equipment Manufacturer
OST-R	Office of the Assistant Secretary for Research and Technology
OTA	Over-the-Air
PHY	Physical [layer]
RCC	Regulatory Cooperative Council
RDS	Radio Data System
RFC	Request for Comment
RFID	Radio Frequency Identification
RSU	Roadside Unit
SAC	Standardization Administration of China
SAE	[Formerly] Society of Automotive Engineers
SCH	Service Channel
SDO	Standards Development Organization
SWG	Standards Working Group
TC	Technical Committee
TC	Transport Canada
TCP	Transmission Control Protocol
TDD-LTE	Time Division Duplex LTE
TISA	Traveler Information Services Association
TPEG	Transport Protocol Experts Group

TTA	Telecommunication Technology Association [Korea]
UDP	User Datagram Protocol
U.S.	United States
USDOT	US Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	V2V + V2I
VANET	Vehicular Ad-hoc Network
VIIC	Vehicle Infrastructure Integration Coalition
WAVE	Wireless Access in a Vehicular Environment
WLAN	Wireless Local Area Network
WSMP	WAVE Short Message Protocol
ZVEI	German Electrical and Electronic Manufacturers Association

## APPENDIX B: RESPONDENTS TO CONNECTED VEHICLE STANDARDS HARMONIZATION SURVEY

In addition to the eleven individuals listed in the table below, eight others completed the survey and chose to remain anonymous.

<b>Name</b>	<b>Affiliation</b>
<b>Hongwei Zhang</b>	Wayne State University
<b>Scott J. McCormick</b>	Connected Vehicle Trade Association, Inc
<b>Ali Maleki</b>	Ricardo Inc
<b>Patrick Chuang</b>	Booz Allen Hamilton
<b>Mike Bauer</b>	TheCarPage
<b>Greg Krueger</b>	Leidos
<b>Tom Schaffnit</b>	A2 Technology Management LLC
<b>Martin Dreher</b>	Bayerischen Medien Technik
<b>Carl K. Andersen</b>	FHWA
<b>Dominic Paulraj</b>	Arada Systems Inc
<b>Name not disclosed</b>	Security Innovation




[Log In \(/account/login/?next=/press/v2v-penetration-in-new-vehicles-to-reach-62-by-202/\)](/account/login/?next=/press/v2v-penetration-in-new-vehicles-to-reach-62-by-202/)

[Register \(/account/register/?next=/press/v2v-penetration-in-new-vehicles-to-reach-62-by-202/\)](/account/register/?next=/press/v2v-penetration-in-new-vehicles-to-reach-62-by-202/) [Contact \(/contact/\)](/contact/)

## ABIresearch<sup>(/)</sup> V2V Penetration in New Vehicles to Reach 62% by 2027

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London, United Kingdom - 19 Mar 2013

Share:  ([https://www.linkedin.com/shareArticle?mini=true&url=https://www.abiresearch.com/press/v2v-penetration-in-new-vehicles-to-reach-62-by-202/&title=V2V Penetration in New Vehicles to Reach 62% by 2027&summary=Read more at abiresearch.com&source=LinkedIn](https://www.linkedin.com/shareArticle?mini=true&url=https://www.abiresearch.com/press/v2v-penetration-in-new-vehicles-to-reach-62-by-202/&title=V2V%20Penetration%20in%20New%20Vehicles%20to%20Reach%2062%25%20by%202027&summary=Read%20more%20at%20abiresearch.com&source=LinkedIn))  ([https://www.facebook.com/sharer/sharer.php?u=https://www.abiresearch.com/press/v2v-penetration-in-new-vehicles-to-reach-62-by-202/&t=V2V Penetration in New Vehicles to Reach 62% by 2027](https://www.facebook.com/sharer/sharer.php?u=https://www.abiresearch.com/press/v2v-penetration-in-new-vehicles-to-reach-62-by-202/&t=V2V%20Penetration%20in%20New%20Vehicles%20to%20Reach%2062%25%20by%202027))  ([http://twitter.com/intent/tweet?url=https://www.abiresearch.com/press/v2v-penetration-in-new-vehicles-to-reach-62-by-202/&text=V2V Penetration in New Vehicles to Reach 62% by 2027](http://twitter.com/intent/tweet?url=https://www.abiresearch.com/press/v2v-penetration-in-new-vehicles-to-reach-62-by-202/&text=V2V%20Penetration%20in%20New%20Vehicles%20to%20Reach%2062%25%20by%202027))

Vehicle-to-vehicle technology based on DSRC (Dedicated Short Range Communication) using the IEEE 802.11p automotive W-Fi standard will gradually be introduced in new vehicles driven by mandates and/or automotive industry initiatives, resulting in a penetration rate of 61.8% by 2027.

ABI Research VP and practice director, Dominique Bonte comments, "While in the US there is a real possibility for a DoT mandate depending on the outcome of the large scale V2X trial being held in Michigan, in Europe the CAR 2 CAR Communication Consortium which counts 12 car OEMs has signed a Memorandum of Understanding to deploy cooperative Intelligent Transport Systems and Services (C-ITS) in Europe from 2015 based on common technical specifications in line with the 2010 EU Directive calling for an urgent implementation of cooperative ITS. Similar initiatives exist in Asia (Japan, Korea and China)."

Despite increasing momentum driven by both governments/regulators and the automotive industry, the deployment of V2V and even more so V2I will take time, as the real safety benefits of V2X only can be realized when a sufficiently large part of the installed vehicle base is connected. However, complimentary technologies such as ADAS on the low end and cellular connectivity on the high end will allow emulating some of the ITS functionality defined for V2X. In particular, the rapid emergence of LTE Advanced featuring very low latency is a good candidate for offering vehicle-to-vehicle communications awaiting the widespread availability of dedicated V2V technology.

ABI Research's new "Intelligent Transportation Systems" Market Data offers quantitative forecast data including hardware shipments and revenues, installed base, and penetration rates by region till 2027. It is part of the Intelligent Transportation Systems (<http://www.abiresearch.com/research/service/intelligent-transportation-systems/>) and Automotive Technologies (<http://www.abiresearch.com/research/service/automotive-technologies/>) Research Services.

ABI Research provides in-depth analysis and quantitative forecasting of trends in global connectivity and other emerging technologies. From offices in North America, Europe and Asia, ABI Research's worldwide team of experts advises thousands of decision makers through 70+ research and advisory services. Est. 1990. For more information visit [www.abiresearch.com](http://www.abiresearch.com) (<http://www.abiresearch.com/>), or call +1.516.624.2500.

**Appendix XXXVI. Toyota InfoTechnology Center, U.S.A., Inc., DSRC: Deployment and Beyond (WINLAB Research Review), (May 2015).**

# DSRC: Deployment and Beyond

WINLAB Research Review  
John B. Kenney  
Toyota InfoTechnology Center, USA  
May 14, 2015

[jkenney@us.toyota-itc.com](mailto:jkenney@us.toyota-itc.com)

1

## Outline

- Introduction to Toyota ITC
- DSRC Background
- DSRC Deployment
- DSRC Challenges
  - Congestion Control
  - Spectrum Sharing
- DSRC Future
- Connecting Vehicles

# Toyota ITC Overview

**TOYOTA**  
INFO TECHNOLOGY  
CENTER, U.S.A., INC.

## Japan HQ

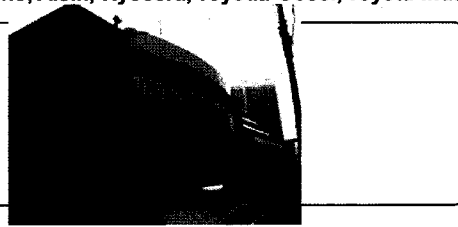
Investors: Toyota, Denso, KDDI, Toyota Tsusho, Aisin, Kyocera, Toyoda Gosei, Toyota Industries

**Headquarters: Tokyo, Japan**

**Location: 6-6-20, Akasaka, Minato-ku**

**Personnel: about 70**

**Established: January, 2001**



## US Center

Wholly-owned subsidiary of Toyota InfoTechnology Center Co., Ltd.

**US HQ and R&D: Mountain View Research Park**

**Location: Mountain View, CA**

**Personnel: about 35**

**Established: April, 2001**



3

**Location: New York City, NY**  
**Business Research**

# DSRC Basics

**TOYOTA**  
INFO TECHNOLOGY  
CENTER, U.S.A., INC.

- Dedicated Short Range Communication
- Dedicated: 5.850-5.925 GHz licensed spectrum
- Short Range: Hundreds of meters
- Vehicle-to/from-X, where X =
  - Another vehicle (V2V)
  - Roadside infrastructure (V2I)
  - Pedestrian, bicycle, train, ...
- Caveat: in Japan and Europe "DSRC" often refers to electronic tolling systems operating in the 5.8 GHz band

# What's it good for?

## 32,719 Traffic Fatalities in 2013

Google

32719 2013



Web Images Maps Shopping Videos More Search tools

About 437,000 results (0.37 seconds)

Images for 32719 2013

Report images



More images for 32719 2013

NHTSA Says 32,719 Died in U.S. Traffic Accidents in 2013 ...

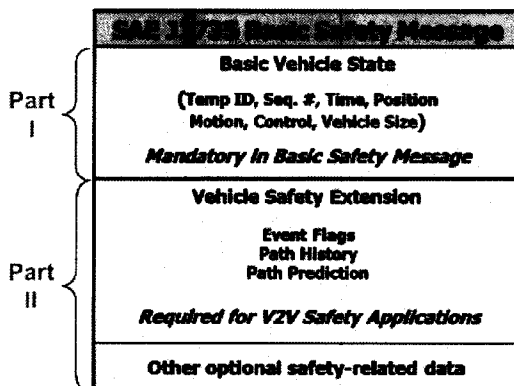
247wallst.com/12/13/32719-died-in-traffic-accidents-in-the-us-last-yea...

Dec 20, 2014 - The rate of deadly traffic accidents dropped 24% from 2004 to 2013

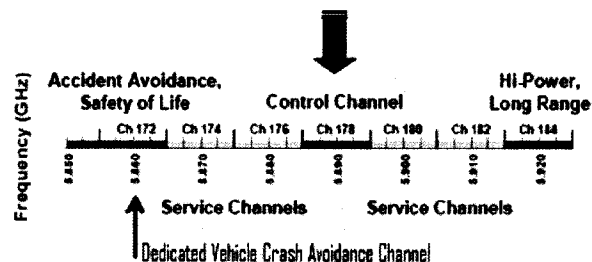
However, 32,719 people were killed last year, according to the National ...

## DSRC V2V Safety Concept

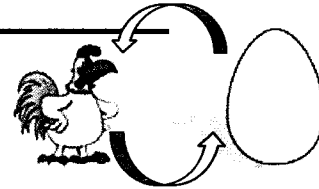
- Concept: each vehicle sends Basic Safety Messages frequently.
- Receiving vehicles assess collision threats
- Threat: Warn driver or take control of car



### 5.9GHz DSRC Spectrum Allocation



# NHTSA DSRC Mandate



- National Highway Traffic Safety Administration
  - Regulator for cars, part of US Dept. of Transportation
- Feb. 2014 – NHTSA announces intention to require DSRC BSM transmitters in light vehicles
- Aug. 2014 – NHTSA issues Advance Notice of Proposed Rulemaking (ANPRM)
- May 13, 2015: US DOT Sec. Foxx announces aggressive regulatory plan
- Early 2016: NPRM expected
- 2017-2018: Finalize regulations
- 2019-2020: Expect initial mandated deployment
- However, GM plans early voluntary Cadillac deployment in model year 2017

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## What else is it good for?

### CONNECTED VEHICLE APPLICATIONS

V2I Safety	Environment	Mobility
Red Light Violation Warning Curve Speed Warning Stop Sign Gap Assist Spot Weather Impact Warning Reduced Speed/Work Zone Warning Pedestrian in Signalized Crosswalk Warning (Transit)	Eco-Approach and Departure at Signalized Intersections Eco-Traffic Signal Timing Eco-Traffic Signal Priority Connected Eco-Driving Wireless Inductive/Resonance Charging Eco-Lanes Management Eco-Speed Harmonization Eco-Cooperative Adaptive Cruise Control Eco-Traveler Information Eco-Ramp Metering Low Emissions Zone Management AFV Charging / Fueling Information Eco-Smart Parking Dynamic Eco-Routing (light vehicle, transit, freight) Eco-ICM Decision Support System	Advanced Traveler Information System Intelligent Traffic Signal System (I-SIG) Signal Priority (transit, freight) Mobile Accessible Pedestrian Signal System (PED-SIG) Emergency Vehicle Preemption (PREEMPT) Dynamic Speed Harmonization (SPD-HARM) Queue Warning (Q-WARN) Cooperative Adaptive Cruise Control (CACC) Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG) Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) Emergency Communications and Evacuation (EVAC) Connection Protection (T-CONNECT) Dynamic Transit Operations (T-DISP) Dynamic Ridesharing (D-RIDE) Freight-Specific Dynamic Travel Planning and Performance Drayage Optimization
V2V Safety	Road Weather	Smart Roadside
Emergency Electronic Brake Lights (EEBL) Forward Collision Warning (FCW) Intersection Movement Assist (IMA) Left Turn Assist (LTA) Blind Spot/Lane Change Warning (BSW/LCW) Do Not Pass Warning (DNPW) Vehicle Turning Right in Front of Bus Warning (Transit)	Motorist Advisories and Warnings (MAW) Enhanced MDSS Vehicle Data Translator (VDT) Weather Response Traffic Information (WxTINFO)	Wireless Inspection Smart Truck Parking
Agency Data		
Probe-based Pavement Maintenance Probe-enabled Traffic Monitoring Vehicle Classification-based Traffic Studies CV-enabled Turning Movement & Intersection Analysis CV-enabled Origin-Destination Studies Work Zone Traveler Information		

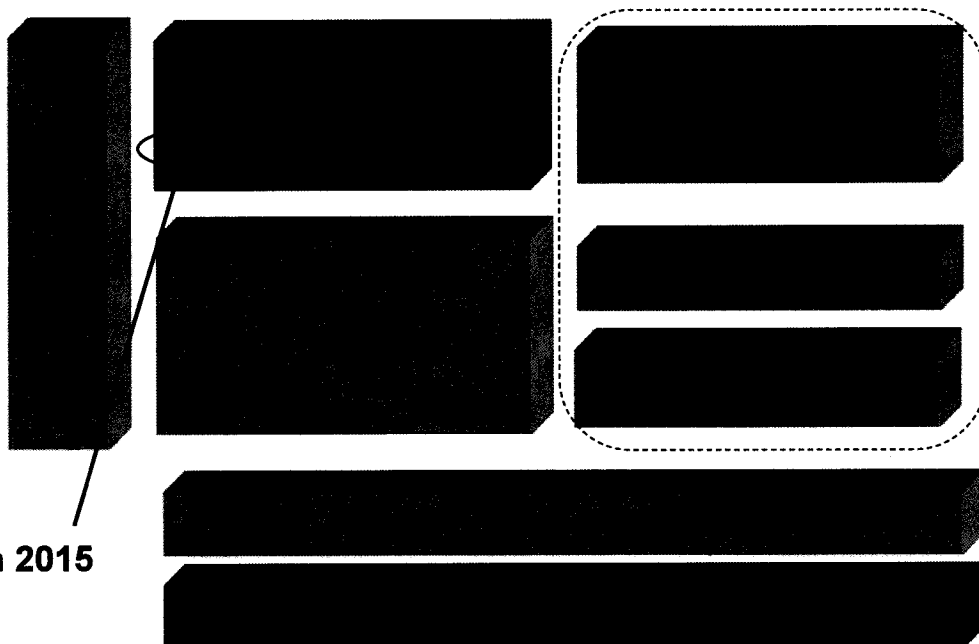
Source: US Department of Transportation

Most of these use V2I DSRC

8

# DSRC Standards

↑  
**TOYOTA**  
INFO TECHNOLOGY  
CENTER, U.S.A., INC.



New in 2015

**NHTSA Requirement: “Stable” standards by Sept. 2015** <sup>9</sup>

See: J. Kenney, “DSRC Standards in the United States”, Proc. IEEE, July 2011, Vol. 99, No. 7, pp. 1162-1182

## Compare US, EU, JP

↑  
**TOYOTA**  
INFO TECHNOLOGY  
CENTER, U.S.A., INC.

### Europe:

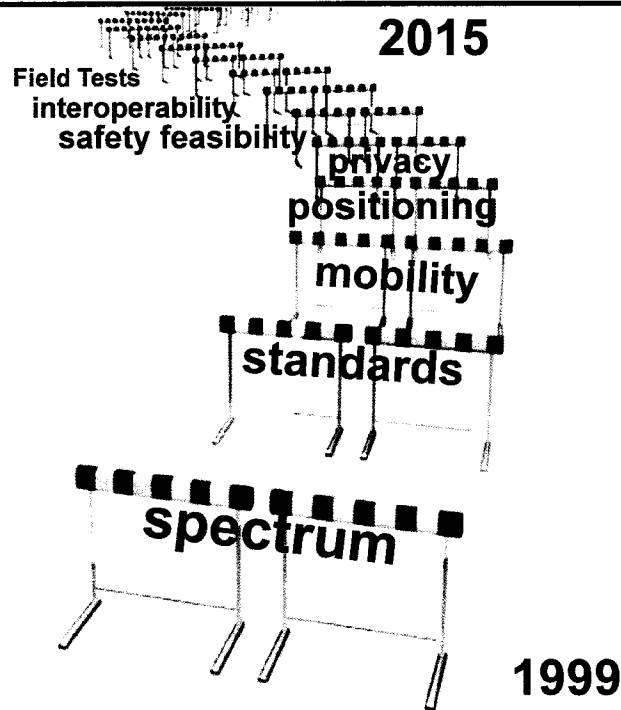
- Cooperative ITS, a.k.a. ITS-G5
- Similar technology (802.11p-based, 5.9 GHz)
- Voluntary deployment model
  - Expect more gradual penetration, perhaps starting earlier
  - More emphasis on “day 1” benefits

### Japan:

- Advanced Safety Vehicle (ASV) – 760 MHz
  - V2V and V2I
  - Toyota voluntary deployment starting 2015
- Driving Safety Support System (DSSS) – 5.8 GHz
  - V2I, many roadside units deployed, many vehicles equipped

# We've come a long way

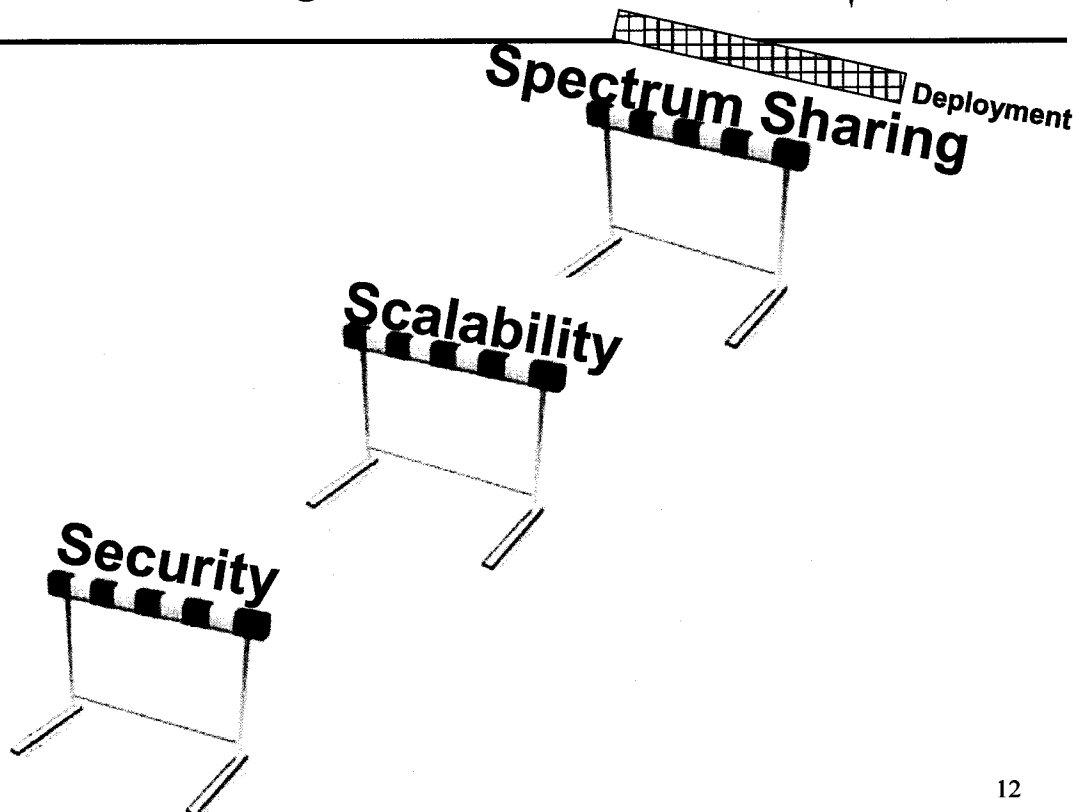
↑  
**TOYOTA**  
INFO TECHNOLOGY  
CENTER, U.S.A., INC.



11

# Still to go ... near term

↑  
**TOYOTA**  
INFO TECHNOLOGY  
CENTER, U.S.A., INC.



12

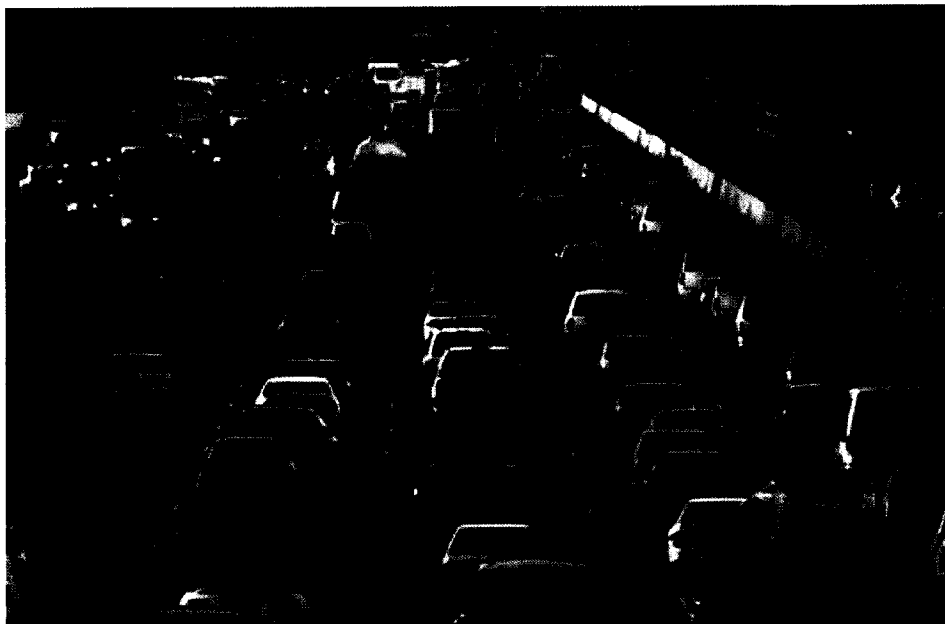
# Security

- Twin goals:
  - Authenticate sender while preserving privacy
- PKI approach: asymmetric cryptography
- Two components
  - Per-message digital signature (pseudonymous)
  - Security infrastructure
    - SCMS: Security Credential Management System
    - Replenish short term credentials
    - Report & Revoke misbehaving actors
- Most technical work is done
- Important policy questions remain
  - Example: who owns/runs SCMS?

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# Scalability

Basic question: will all this still work here?



14

# Biggest concern: BSM safety channel congestion

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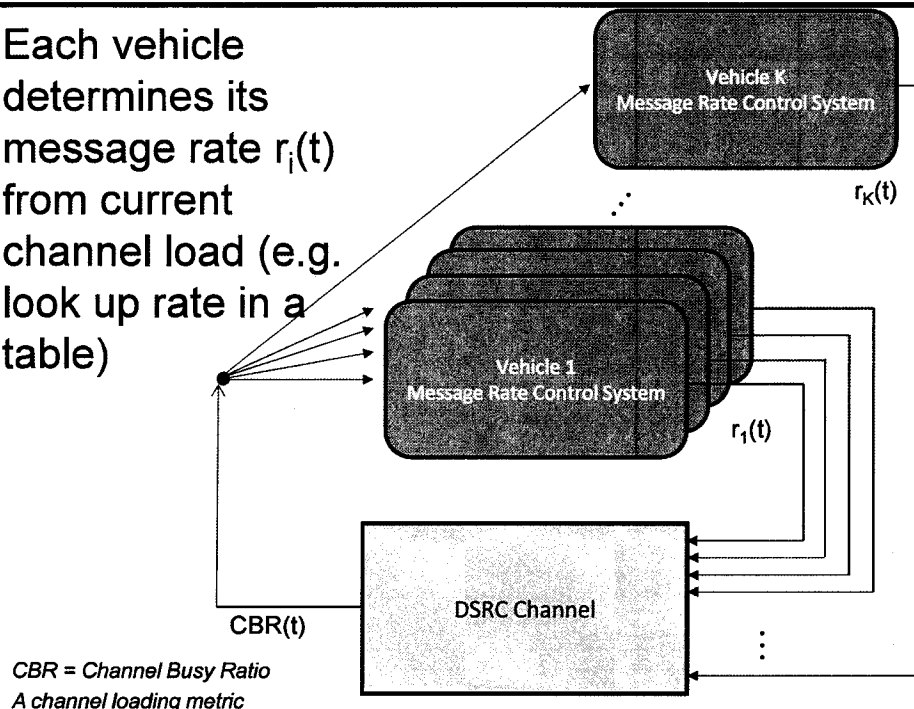
- Subject of a much published research
- Automaker consortium has researched two main approaches, in cooperation with US DOT
- Main distinction: Reactive vs. Adaptive Control
- Secondary distinction: Emphasis on message rate vs. transmit power control



## Distributed Reactive Control

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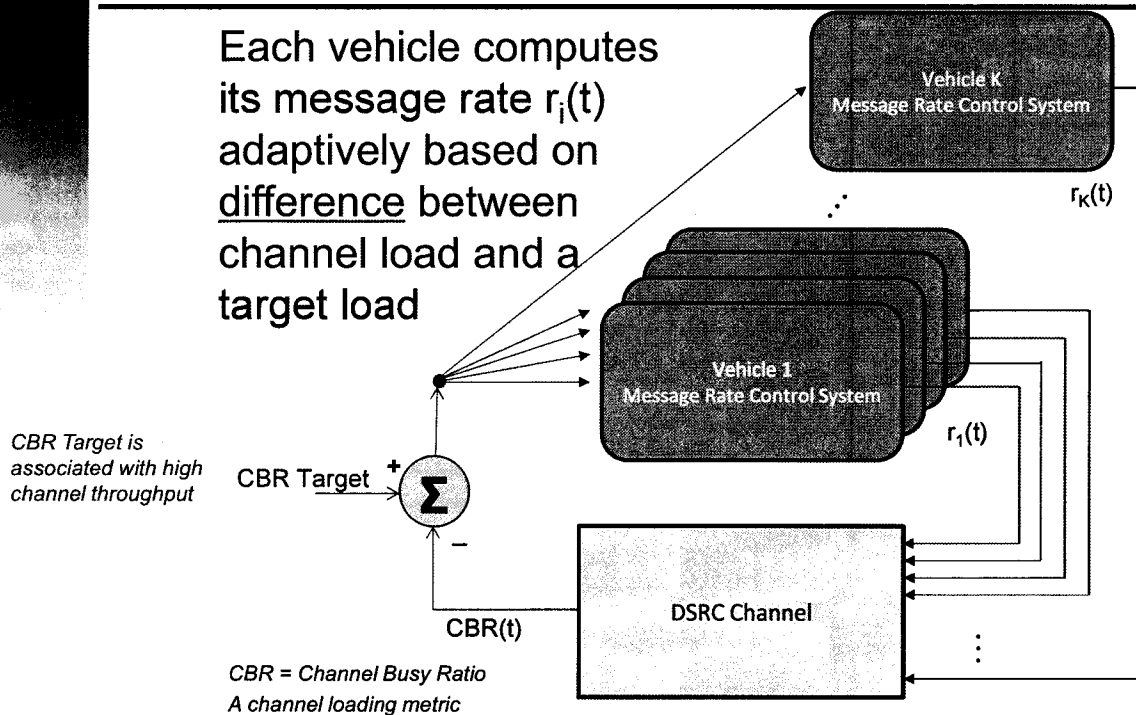
Each vehicle  
determines its  
message rate  $r_i(t)$   
from current  
channel load (e.g.  
look up rate in a  
table)



Can equivalently control power, or both power & rate

# Distributed Adaptive Control

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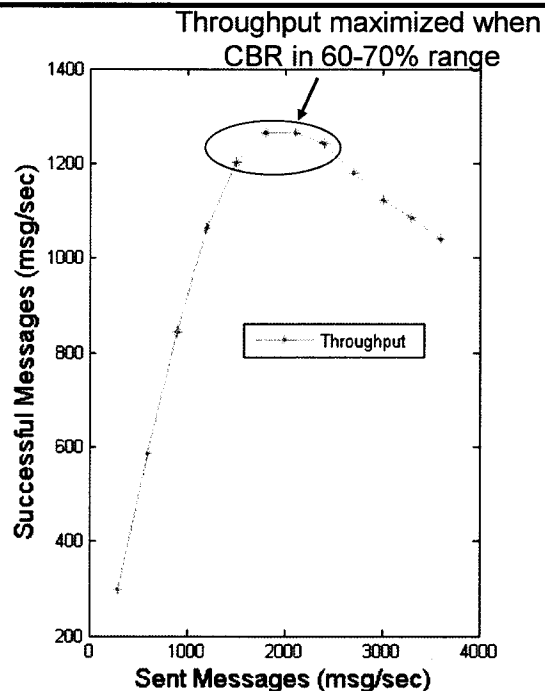
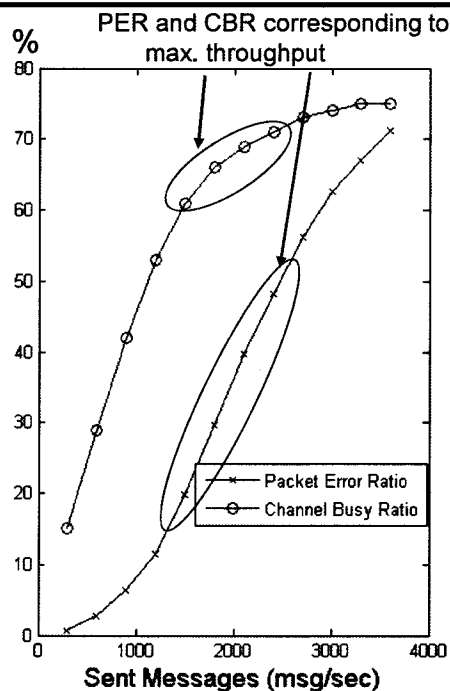


17

Algorithm Goals: controlled load, convergence, fairness

## Why drive CBR to target?

TOYOTA  
INFO TECHNOLOGY  
CENTER, U.S.A., INC.



- An Adaptive DSRC Message Transmission Rate Control Algorithm, Weinfield, Kenney, Bansal, ITS World Congress, October 2011
- Cross-Validation of DSRC Radio Testbed and NS-2 Simulation Platform for Vehicular Safety Communications, Bansal, Kenney, Weinfield, IEEE WIVec Symposium, September 2011

- Linear MESSage Rate Integrated Control
- Provable stability, convergence and fairness

$$r_j(t) = (1 - \alpha)r_j(t-1) + \beta(r_g - r(t-1))$$

Rate for node j      CBR Target      Current CBR

$e(t-1)$

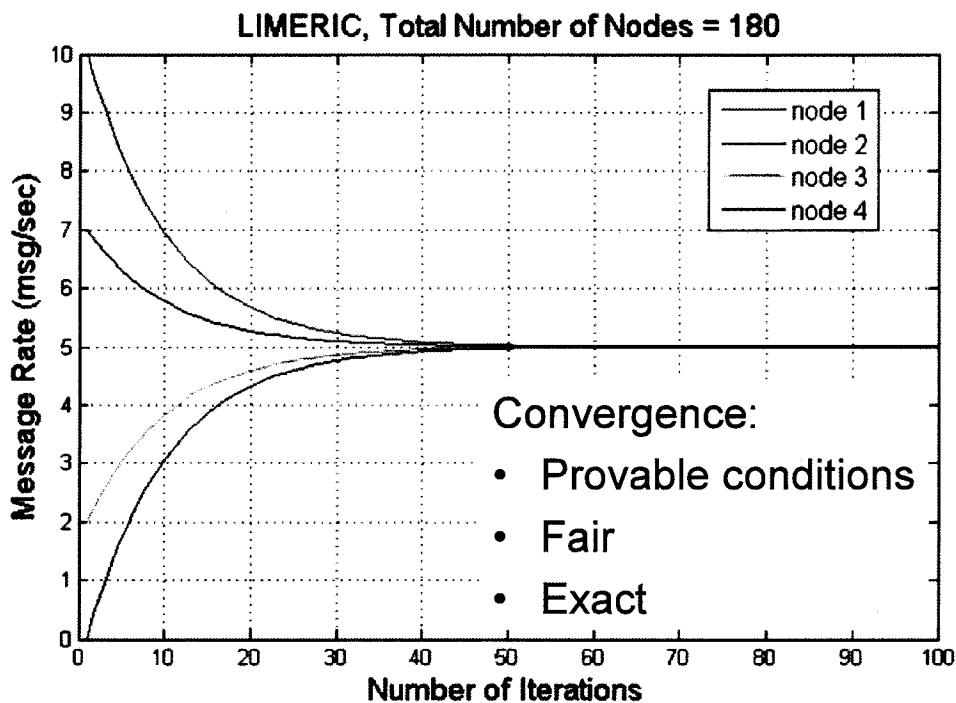
$0 < \alpha < 1$  : contraction parameter,  
Impacts fairness, convergence speed

$\beta > 0$ : linear gain adaptive parameter,  
Impacts stability, convergence speed

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LIMERIC: A Linear Adaptive Message Rate Algorithm for DSRC Congestion Control, Bansal, Kenney, Rohrs, IEEE TVT Nov. 2013

## Example fair convergence



20

**TOYOTA**  
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CENTER, U.S.A., INC.

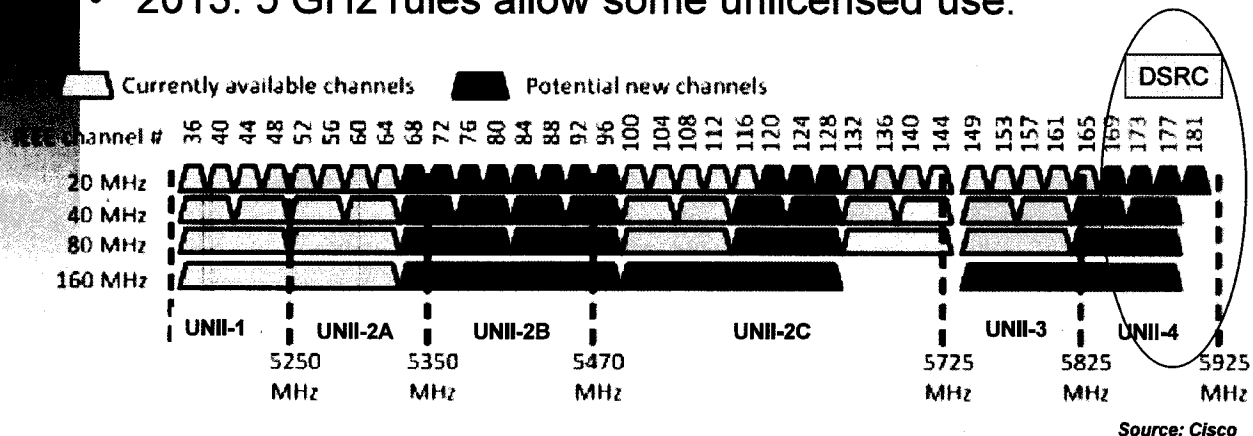
- Critical for NHTSA Rulemaking, so needs to be standardized in 2015
  - SAE will standardize in J2945/1
- EU (ETSI/Car2Car) facing similar choice
  - Decided on a “reactive” approach for Day 1
  - Considering allowing adaptive approach
  - Mixed network behavior is critical

21



**TOYOTA**  
INFO TECHNOLOGY  
CENTER, U.S.A., INC.

- 2013: 5 GHz rules allow some unlicensed use:

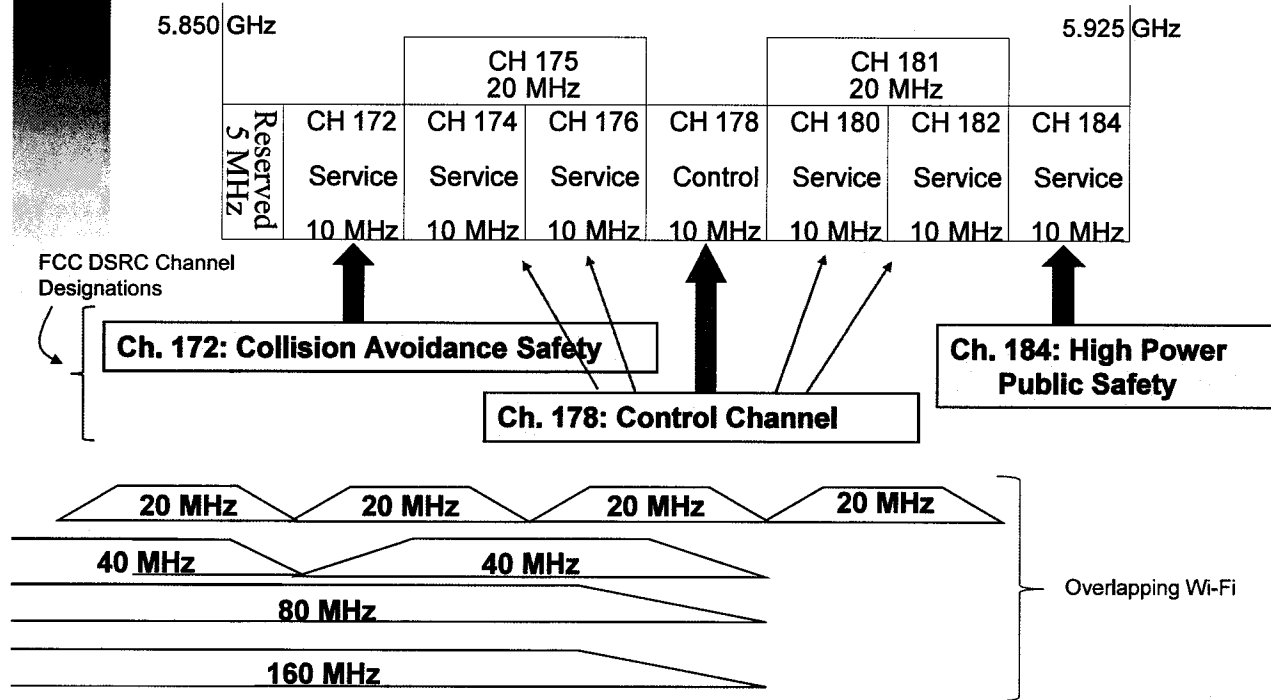


- New IEEE 802.11ac (Gigabit Wi-Fi) standard allows 80 MHz and 160 MHz channels. Need large new blocks.
- Potential to add 4 new 80 MHz and 3 new 160 MHz channels in 5 GHz band.
  - One 80 and one 160 MHz channel in DSRC 5.9 GHz band

22

# Zoom in to 5.9 GHz band

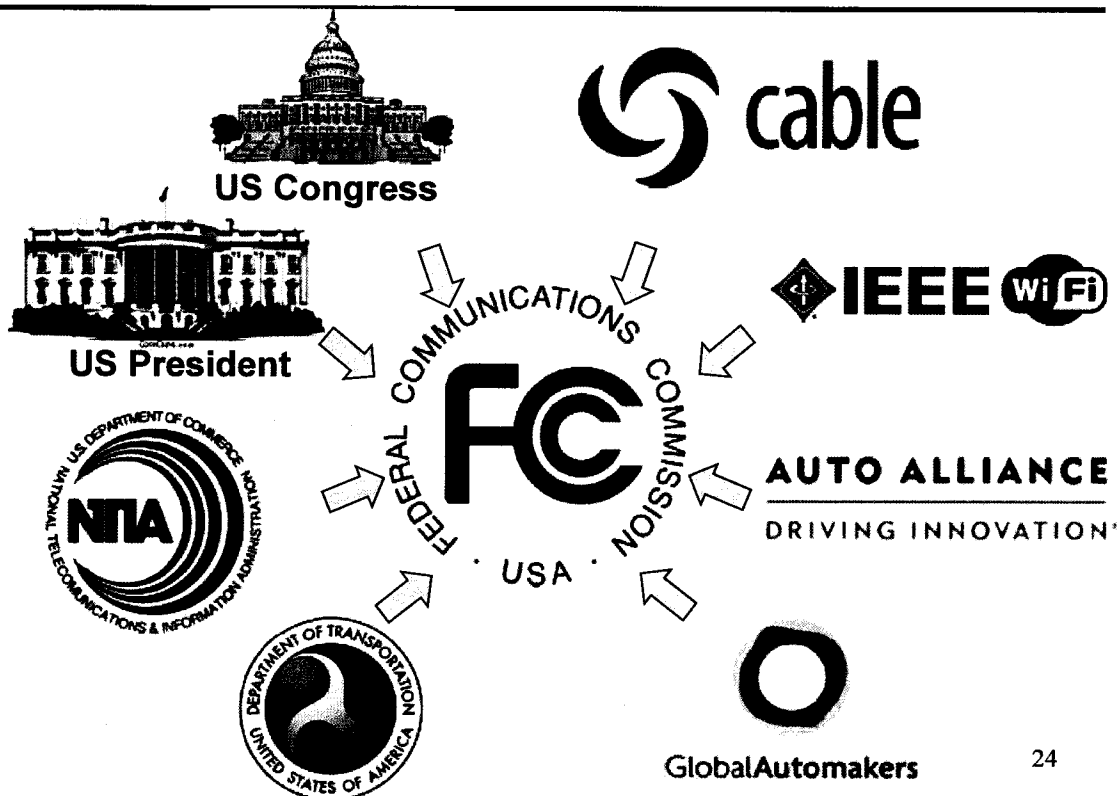
TOYOTA  
INFO TECHNOLOGY  
CENTER, U.S.A., INC.



23

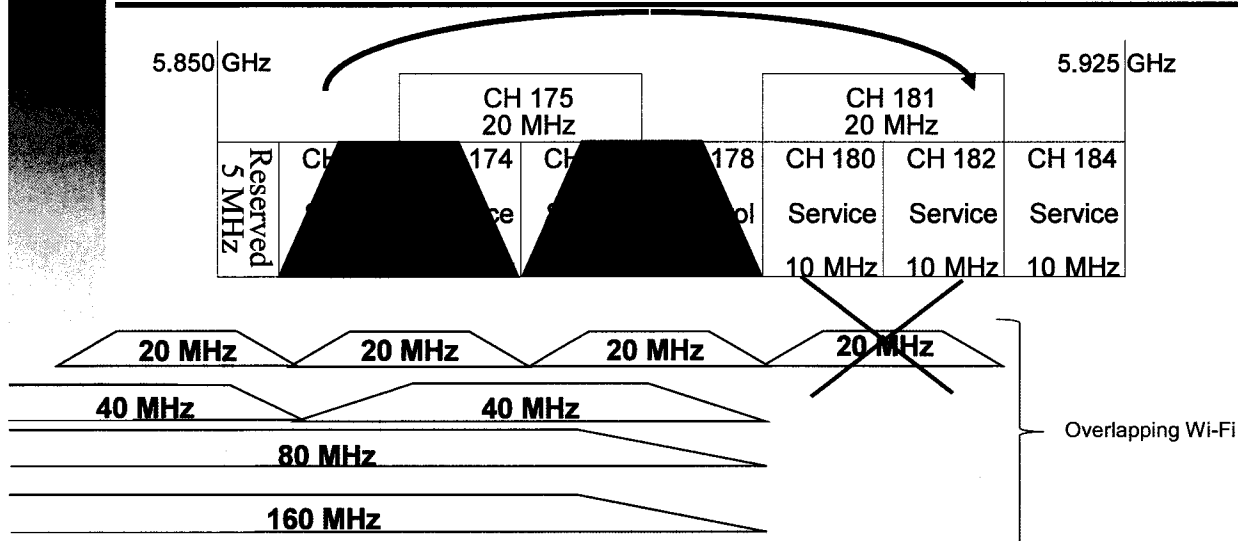
# Major Stakeholders

TOYOTA  
INFO TECHNOLOGY  
CENTER, U.S.A., INC.



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# Qualcomm Proposal

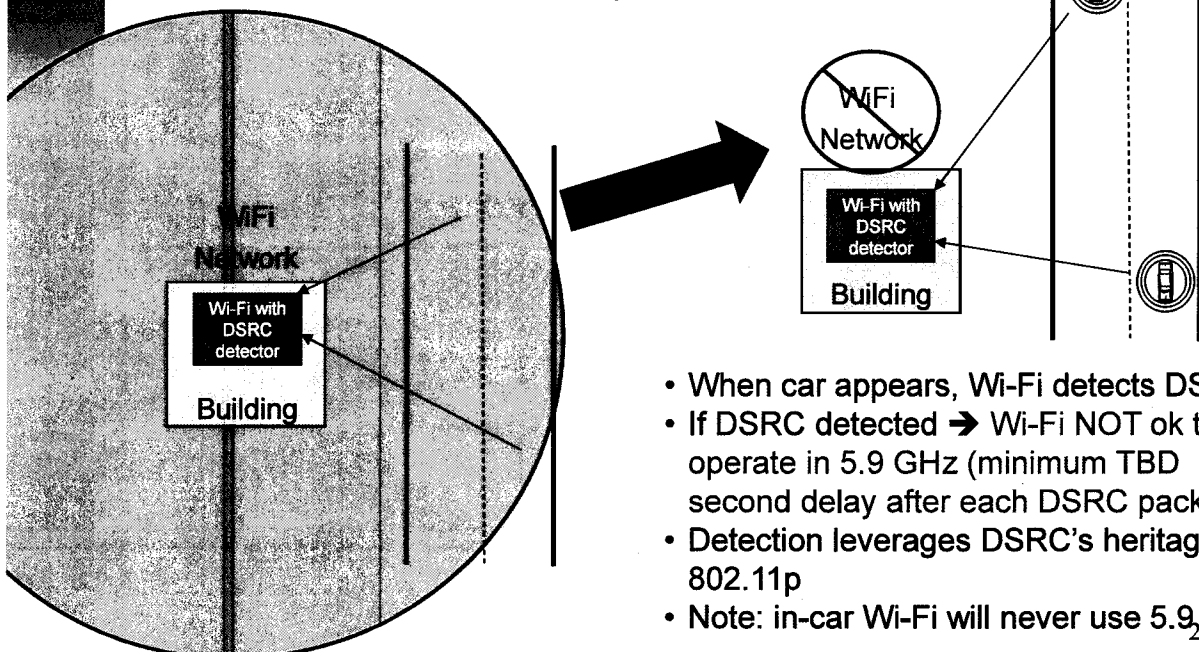


- Move DSRC safety from Ch. 172 to upper band (non-overlap portion)
- Cancel highest 20 MHz Wi-Fi (Ch. 181)
- DSRC use 20 MHz channels in overlap portion instead of 10 MHz

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# Cisco Proposal

- Wi-Fi devices listen for DSRC
- If no DSRC → Wi-Fi ok to operate in 5.9 GHz
- Continues to listen while WLAN operates



- When car appears, Wi-Fi detects DSRC
- If DSRC detected → Wi-Fi NOT ok to operate in 5.9 GHz (minimum TBD second delay after each DSRC packet)
- Detection leverages DSRC's heritage as 802.11p
- Note: in-car Wi-Fi will never use 5.9<sub>20</sub> GHz

# Spectrum Sharing Milestones

TOYOTA  
INFO TECHNOLOGY  
CENTER, U.S.A., INC.

- Feb. 2013: FCC issues NPRM for 5 GHz
  - Asks if 5.9 GHz sharing is feasible
- Aug. 2013: IEEE forms "Tiger Team"
  - DSRC stakeholders participate fully
- Fall 2013: Qualcomm and Cisco offer sharing proposals
- Nov. 2013: Congressional hearing
- Winter 2014: Sen. Rubio bill puts pressure on FCC
- Sept. 2014: DSRC critiques Qualcomm proposal
  - Also indicates Cisco proposal has potential
- March 2015: Tiger Team ends
  - Poll of participants shows strong support for additional work on Cisco proposal, weak support for Qualcomm
- May 5 2015: Auto Trade Associations and Cisco tell FCC about plans for joint testing

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# Spectrum Sharing Milestones

TOYOTA  
INFO TECHNOLOGY  
CENTER, U.S.A., INC.

- May 13, 2015: US DOT Sec. Foxx promises to test within 12 months of receiving prototype sharing equipment

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**NHTSA**

NATIONAL HIGHWAY TRAFFIC  
SAFETY ADMINISTRATION

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Jobs at NHTSA

Presentations &  
Speeches

Highway Safety  
Grant Programs

Traffic Techs

## Transportation Sec. Foxx announces steps to accelerate road safety innovation

DOT 49-15

Wednesday, May 13, 2015

Contact: Gordon Trowbridge, ☎ 202-366-8550, Public.Affairs@dot.gov

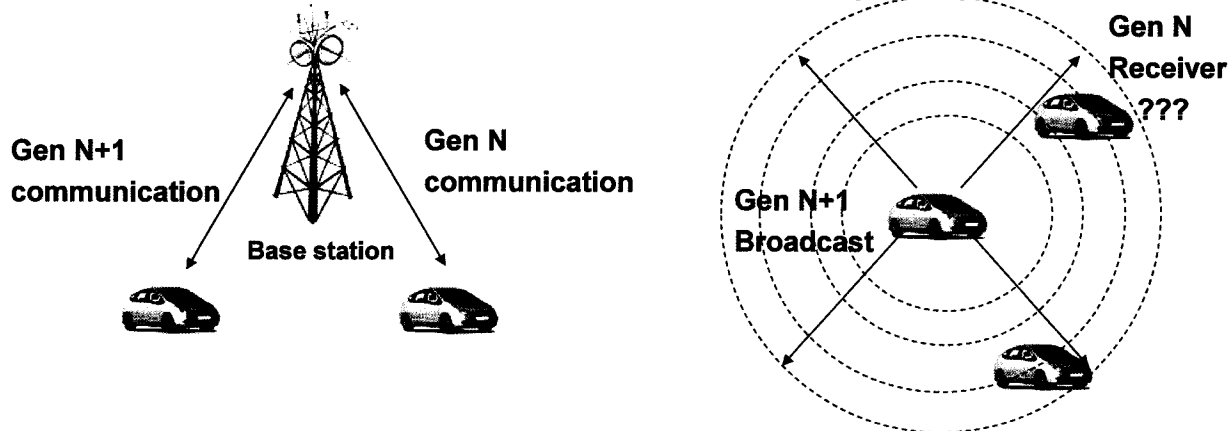
**Pushing V2V forward, modernizing regulatory framework aimed at speeding up technologies that can save lives, reduce crashes**

MOUNTAIN VIEW, Calif. - U.S. Transportation Secretary Anthony Foxx was at Delphi Labs @ Silicon Valley today to announce a series of steps to speed life-saving technology innovations to America's highways. He also pledged to work with the auto industry and technology companies to ensure that vehicle automation technologies with demonstrated safety benefits can come to market. Secretary Foxx was in California as part of his tour to highlight our nation's third annual Infrastructure Week, which brings together thousands of stakeholders across the country to highlight the importance of investing in America's infrastructure future.

# Post-deployment challenge: Protocol evolution

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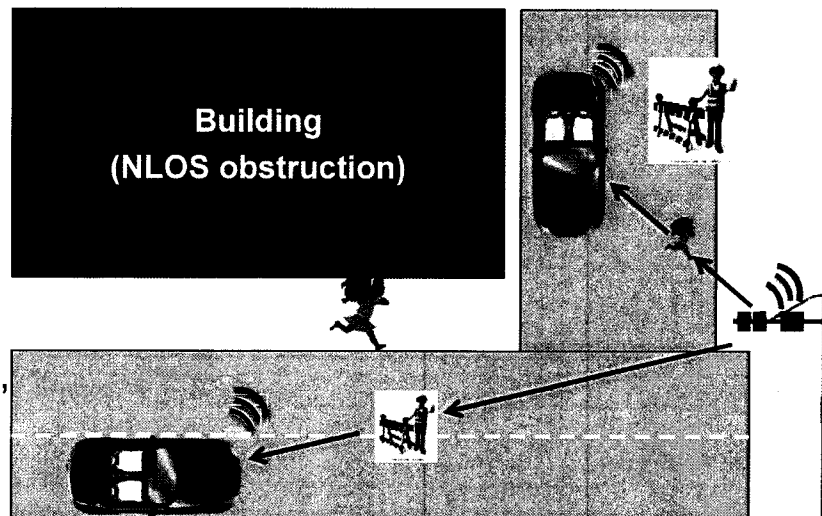
- Contrast master-slave network with ad hoc
- Master (Base station, Access Point) can manage multiple generations of clients
- Ad hoc:
  - Unicast or small group: Negotiation to common protocol generation
  - Broadcast: ???
- Evolution of lower layers more difficult than higher layers



## What else is it good for? Remote sensing for automated driving

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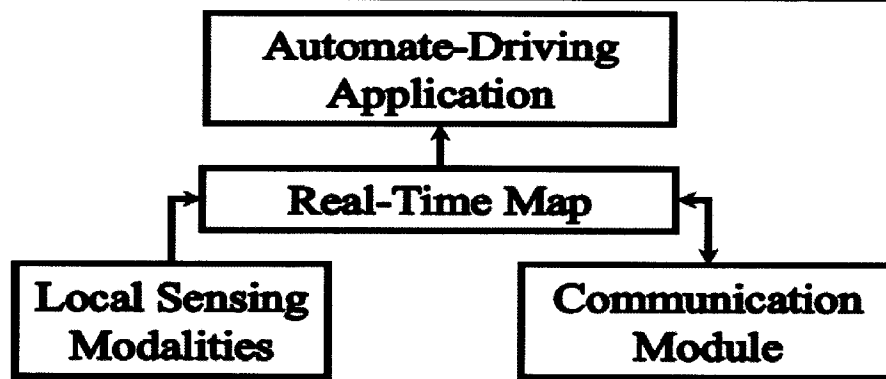
Non-line-of-sight (NLOS) obstacles are a major challenge for automated vehicles, especially at intersections



Sharing sensor information can improve an automated vehicle's awareness of potential hazards, including pedestrians, bicyclists, other vehicles, road works ...

## Augmenting & Sharing Real-Time Map

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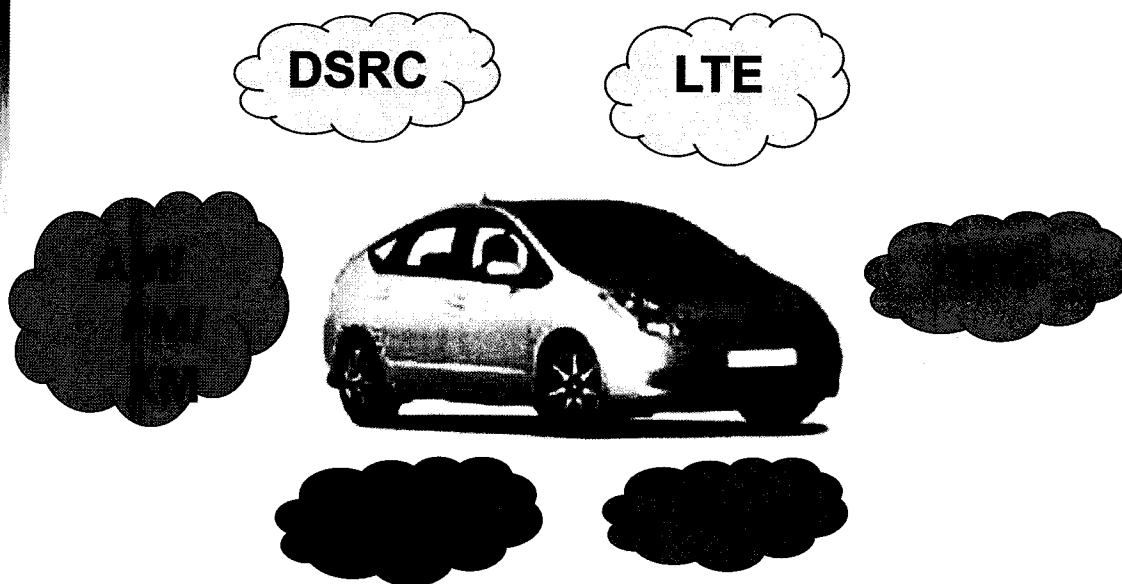


- Scalability is a concern
- Need adaptive content management
- ***“Connected, automated vehicles that can sense the environment around them and communicate with other vehicles and with infrastructure have the potential to revolutionize road safety and save thousands of lives.” – US DOT Sec. Foxx 5/13/15***

"Adaptive Content Control for Communication amongst Cooperative Automated Vehicles," M. Fanaei, A. Tahmasbi-Sarvestani, Y. Fallah, G. Bansal, M. Valent, and J. Kenney, *IEEE WIVEC 2014*

## Connected Car

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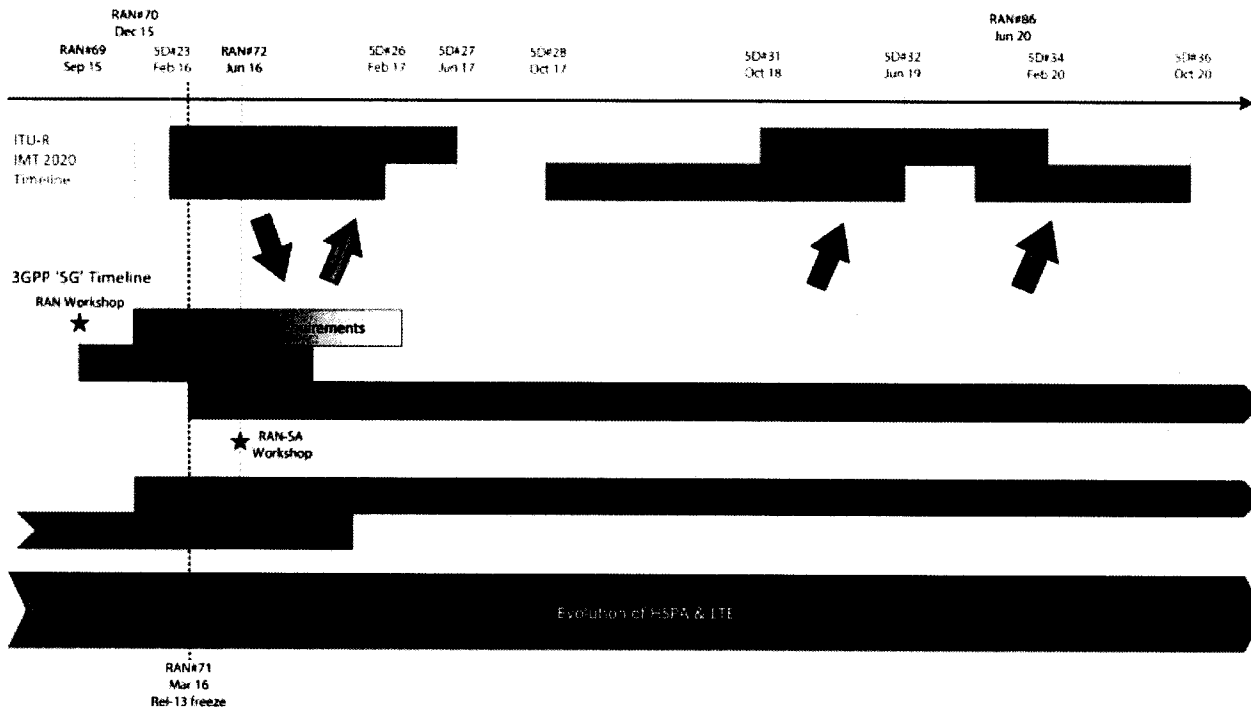


- ***Connecting with many things, in and out of the car***
- ***New modalities being added all the time***

# What about 5G for V2X?

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## 3GPP/ITU-R Timeline for 5G (3/17/15)



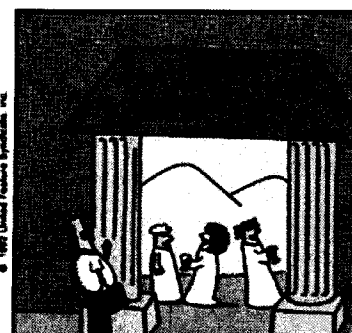
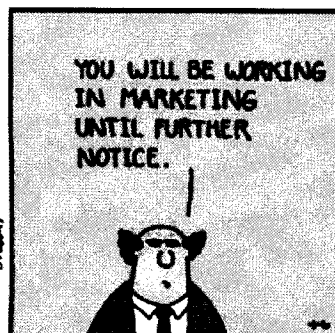
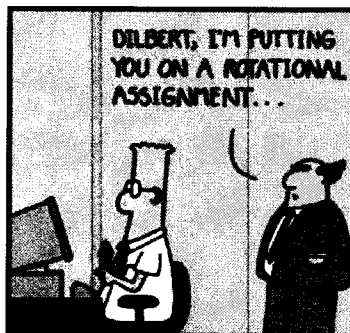
## "5G"

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**Note:** As was the case with the previous generation - 3GPP does not intend to explicitly use the term "5G" when the work starts. "5G" will remain a marketing & industry term that companies will use as they see fit.

- Dino Flore, Chairman of 3GPP RAN and Balazs Bertenyi, Chairman of 3GPP SA

Monday April 06, 1992



"When I use a word," Humpty Dumpty said in rather a scornful tone, "it means just what I choose it to mean -- neither more nor less."

- Humpty Dumpty in Lewis Carroll's *Through The Looking Glass*

# 3GPP Work on V2X

- Recent study begun in SA1 (Services WG)
- Many use cases brought to April 2015 meeting:
  - Forward Collision Warning
  - Control Loss Warning
  - Emergency Vehicle Warning
  - Emergency Stop
  - C-ACC
  - Queue Warning
  - Road Safety Services
  - Automated Parking
  - Wrong way driving
  - Message Transfer
  - Pre-crash Sensing
  - Traffic Flow Optimization
  - Curve Speed Warning
  - Pedestrian Collision
  - Vulnerable Road User Safety
- Company contributions: LG, Ericsson, Huawei, Qualcomm, ETRI, Samsung, CATT, IPCom, Intel, Interdigital, Nokia, KT Corp., Sony

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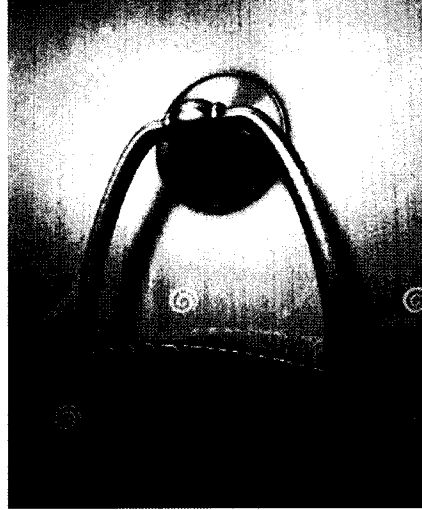
# 3GPP Work on V2X

- Observation #1: Most use cases have safety implications
- Observation #2: Automakers are not proposing these use cases
- Toyota believes 5.9 GHz DSRC is the only technology that has been demonstrated to deliver safety-relevant information with sufficiently low latency and high reliability
- LTE/5G may offer excellent vehicle connectivity options
- We are interested to see this work progress
- Suggest use cases emphasizing non-safety applications be given more attention

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# What else is DSRC good for?

↑  
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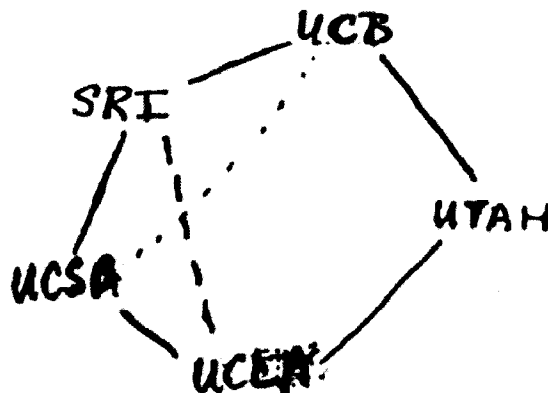


## *Invitation for Innovation*

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Larry Roberts' ARPANET topology diagram, ca. 1969  
Source: *Where Wizards Stay Up Late*

**Some great things began as small ideas**

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**Appendix XXXVII. Main Roads Western Australia, *Connected Vehicles: Are we ready?***  
**(June 2015).**



**mainroads**  
WESTERN AUSTRALIA

**ROAD NETWORK  
OPERATIONS**

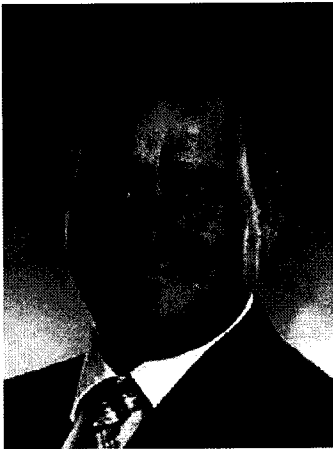
# Connected Vehicles:

**INTERNAL REPORT ON POTENTIAL  
IMPLICATIONS FOR MAIN ROADS WA**



JUNE 2015

## Message from Managing Director of Main Roads WA



I am pleased to release this report on Connected Vehicles, a companion to the comprehensive report, 'Automated Vehicles: Are we ready?', which was prepared by our Road Network Operations team and released in February 2015. The first report was well received and serves as an important background report aligned with our corporate strategic direction, *Keeping WA Moving*.

Following the excellent reception to our 'Automated Vehicles: Are we ready?' report, I asked the Road Network Operations team to produce a companion report on Connected Vehicles and the team have once again produced a high standard document. The focus on Connected Vehicles will help us better understand the transition to Automated Vehicles.

Development of Connected Vehicles is happening concurrently with Automated Vehicles. Both the US and European car manufacturers have been working to include Cooperative Intelligent Transport Systems (C-ITS) in their new vehicles in the 2016-2020 timeframe. Japan has already deployed vehicles with V2I (Vehicle-to-Infrastructure) and I2V (Infrastructure-to-Vehicle) C-ITS capability. With over 85 percent of Australia's cars being imported, vehicles with C-ITS capabilities can be expected on our roads soon after they are deployed internationally.

While Austroads has been leading Australia's preparation for C-ITS at a national level, we need to take the lead in this for Western Australia. Establishing any roadside communication infrastructure required for C-ITS, particularly for communication between

our traffic signals and vehicles will be a key part of our response.

A key driver for C-ITS from a road agency perspective is the potential safety benefits from advanced C-ITS safety applications that will reduce the number of fatalities and serious injury crashes on our road network in both urban and rural areas. Advanced C-ITS safety applications have the potential for a step-change increase in road safety and will provide us with a much needed new tool in our efforts towards 'Vision Zero' with its aim of ultimately achieving no fatalities and serious injury crashes on our roads.

I hope you will find this report as interesting and informative as our 'Automated Vehicles: Are we ready?' report. We received some good feedback from inside and outside the organisation to this first report, and I expect this companion report will be equally well received. The next step will be to organise a workshop to develop an action plan in response to the potential implications highlighted by these two reports.

A stylized, handwritten signature in black ink.

**Steve Troughton**  
Managing Director of Main Roads

## Executive Summary

In the context of smart vehicles, rapid technological developments are occurring within two separate areas defined as Automated Vehicles (AVs) and Connected Vehicles (CVs). The development of CVs and AVs is occurring largely independently, although convergence of the two areas will be required for full automation of vehicles.

In general, the term 'Connected Vehicle' is used to broadly identify any 'smart vehicle' with wireless connectivity to the Internet, local network or the Cloud, other vehicles, personal communication devices, roadside infrastructure or control centres for real-time communication or exchange of data.

C-ITS (Cooperative Intelligent Transport Systems) is more focussed on Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) wireless communications that are used to share real-time information about the road environment (such as potential incidents, threats and hazards) with an increased time horizon and awareness distance, beyond current in-vehicle technologies (radars or cameras) and what the driver can visualise. C-ITS is considered a subset of CVs.

This report is a companion report to 'Automated Vehicles: Are we ready?' and discusses the imminent availability of C-ITS enabled vehicles on Western Australian roads, and what Main Roads, as the state road agency, needs to do to enable successful operation of such vehicles on its road network.

From a government perspective, the impetus for deploying C-ITS is to deliver applications with a road safety

focus that will reduce the number of fatality and serious injury crashes on the road network. To do this effectively, C-ITS will need to function in urban and rural areas, particularly as rural Western Australia (WA) contributes to a significant number (58 percent) of fatal crashes (based on 2009–2014 crash data) each year.

Main Roads' primary interest would be to support applications that deliver significant safety, efficiency and environmental benefits for its customers.

Emerging CV applications that are more commercially driven including infotainment, traveller information and navigation are being developed and deployed in vehicles by auto manufacturers and technology companies independently of road agencies.

Although significant progress has been made under the leadership of Austroads and other agencies, there are still challenges to be resolved at a national level for C-ITS to be successfully deployed in Australia. In particular, spectrum management and device licensing, standards development and compliance, security and trust (Security Credential Management System), privacy, vehicle positioning, digital mapping, global harmonisation, and defining the roles and responsibilities for C-ITS need to be addressed.

Successful C-ITS deployment will require a targeted list of non-complex day-one applications that deliver value to customers. These applications will need their own set of defined roles and responsibilities, roll-out plans,

hot spot areas, investment plans and related business cases.

While day-one applications are not directly linked to a specific communication technology, they will have different operational requirements such as latency that may require specific communication technologies to be used for successful operations. There are already several access technologies [such as FM/DAB+ (Digital Audio Broadcasting) radio, mobile broadband, 5.9 GHz DSRC (Dedicated Short Range Communication) and satellite] that could be used for C-ITS applications, and it is expected that new technologies will emerge on a regular basis.

Good service provision will require access to multiple communications technologies for the best outcomes in relation to costs, reliability and safety, particularly in regional WA.

It is also important that the C-ITS applications are based on standardised message sets and have been tested and validated in relevant field operation tests.

What Main Roads may need to do to support these day-one applications and the initial C-ITS deployment is still emerging through the Austroads-led work being undertaken nationally.

However, it appears Australia's preferred approach would be to put in place the policy, legal and regulatory frameworks to support C-ITS by addressing key deployment challenges. These include spectrum management and device licensing, assurance and compliance with standards, and security and trust.

This will leave it largely to the competitive market to deploy C-ITS with supporting roadside infrastructure provided by the respective road agencies at jurisdiction level.

As a road agency Main Roads, over the next two to three years, will need to ensure that data management and data access processes in relation to road agency data such as speed zones, SPaT (Signal Phasing and Timing), intersection geometry and road works, are improved and aligned to support and facilitate emerging C-ITS applications, in sync with other jurisdictions.

Also, Main Roads ITS control systems such as STREAMS and SCATS need to be integrated and updated to support day-one C-ITS applications. Until what is expected of road agencies becomes clearer, there are two possible alternative positions for Main Roads to take regarding roadside infrastructure required for C-ITS.

- a) Do not deploy Road-side Units (RSUs) and wait for communication options such as 4G and 5G mobile communications, and satellite communications to emerge.
- b) Deploy limited RSUs in critical corridors and hot spots such as rail crossings with a poor safety record.

Scenario (a) still provides access to the opportunities of CVs but it may take a longer to allow communications technology to mature. Scenario (b) involves deploying limited RSUs along selected critical corridors such as high-volume roads and hot spots. However, because technology

requirements are not clear, a limited rather than network-wide deployment initiative may be of more benefit. A commitment to a test corridor and to install RSUs on new roads (eg. Perth Freight Link and NorthLink due to open in 2019) would also provide greater certainty to encourage private investment.

It has been proposed that around AUD 15 million to install C-ITS at prioritised locations in WA would provide a modest investment in roadside infrastructure and adequately support traffic management control systems for the foreseeable future.

In summary, the following action plan is recommended for the next two to three years, until what's required in relation to C-ITS emerges and informs road agencies:

1. Continue participating in the current national Austroads' led national policy and regulatory processes.
2. Identify and implement the changes required in STREAMS and SCATS to support day-one C-ITS applications.
3. Ensure data management and data access processes in relation to road agency data such as speed zone, SPaT, intersection geometry and roadworks, are improved and aligned to support and facilitate emerging C-ITS applications.
4. Identify and implement the communication changes required for existing and new ITS to future proof them for C-ITS applications.
5. Continue to facilitate the transition to the National ITS Architecture.

6. Develop in-house capabilities, particularly in ITS architecture and systems engineering, and exploit Big Data from CVs.
7. In partnership with academia and industry, establish a local test-bed to examine readiness of C-ITS applications, and undertake research and development activities for WA specific issues in the deployment of CVs and AVs.
8. Commit to deploying RSUs on new and upgraded roads due to open beyond 2017, such as Perth Freight Link and NorthLink, and hot spots such as rail crossings with poor safety records.